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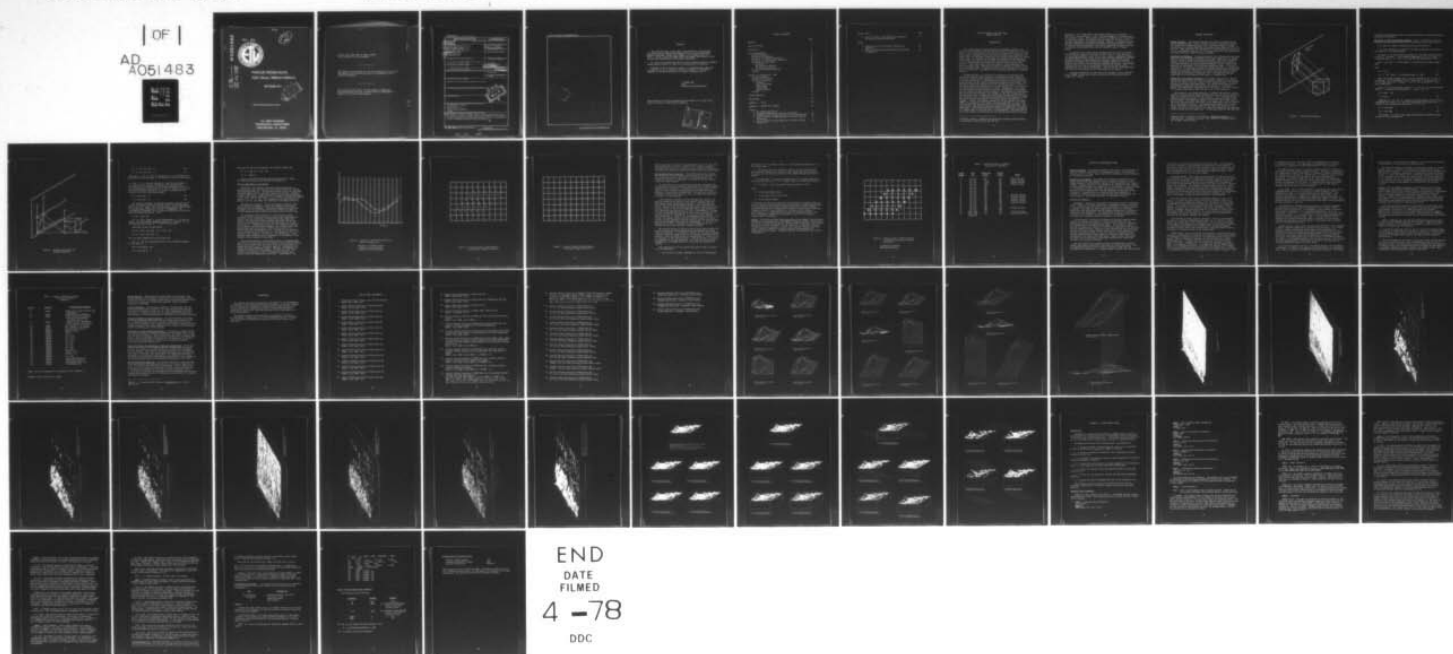
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Foreword

The work described in this report was performed in the Automated Cartography Branch, Mapping Developments Division, United States Army Engineer Topographic Laboratories (USAETL), by a student intern, Mr. Cyrus C. Taylor, during the summer months June-August 1976 as part of his training and familiarization with Branch activities.*

Mr. Taylor is attending MIT where he plans to obtain a degree in Physics. During breaks from MIT, Mr. Taylor is continuing work in this area.

Although initially started in support of an on-going task, this work is considered to be of sufficient interest to members of the mapping community to warrant publication as a separate technical report.

W. HOWARD CARR
Chief
Automated Cartography Branch

*Encouragement and technical guidance were provided to Mr. Taylor by Mr. James R. Jancaitis, Branch Project Engineer.

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PARALLEL PROFILE PLOTS FOR VISUAL TERRAIN DISPLAY

INTRODUCTION

The representation of three-dimensional topographic surfaces in a format readily comprehended by most people has been a problem for centuries. Terrain can be quantitatively represented by placing contour lines on a map. Unfortunately, although contour lines present quantitative information in a manner simple to understand, many people have trouble visualizing the terrain represented. In an attempt to supplement the quantitative information of contour maps with a more readily visible representation of the topography, a form of three-dimensional perspective views of the terrain has been produced. These views derive their impression of three dimensions from plotted profile lines. These profile lines are composed of discrete elevation measurements taken at regular intervals along a straight line over the surface of the earth. Successive profile lines are separated by a constant interval.

Another approach to the problem of qualitatively representing the terrain has been the oblique projection of terrain profiles, previously identified at ETL¹ as more appropriate and efficient for the presentation of terrain information. As with perspective views, the oblique projection gives substance to the surface by plotting successive profile lines. The difference between the perspective and the oblique projection is that in the oblique projection the projecting rays are parallel and in the perspective projection the rays converge to a point. Consequently, the oblique is a more metric portrayal in that lines that are parallel on the surface are also parallel in the oblique projection. The distances are represented more accurately because there is no change of scale when moving from one profile to the next. Although both the oblique and perspective projections have different scales in the cross-profile direction (as compared to along the profile scale), the oblique's is constant and the perspective's is variable. Further, the previous research at ETL has resulted in software, THREED, for producing a wide range of oblique projections for very large data sets that were much more efficient than perspective algorithms. For these reasons, this oblique projection software was identified for further development. The oblique projection presents the quantitative information in a format easier to use than does a true perspective. The first part of this report details the derivation of the equations specifying the oblique

¹ Jancaitis, James R., "Modeling and Contouring Irregular Surfaces Subject to Constraints," ETL-CR-74-19, pps 161-166.

projection. As is shown below, the oblique projection is completely specified by four parameters: scale, vertical exaggeration, viewing angle, and projection angle. The previously developed software, which is the basis of this work, allowed the complete range of values for the plots' scale, vertical exaggeration, and projection angle. However, to maintain the basic algorithm efficiency of the original software, only viewing angles of $+45^{\circ}$, 0° , and -45° could be specified. This report summarizes research resulting in software modifications which allow the complete range of viewing angles.

In addition, this report details attempts that were made to alleviate two difficulties inherent in parallel profile plots: (1) the difficulty in overlaying planimetry (roads, rivers, etc.) against a background composed of closely spaced profile lines; and (2) the long time required to plot the oblique projection of large quantities of data on digital pen plotters. Research is discussed that involves the systematic deletion of portions of profiles that convey little information regarding the terrain. This creates blank areas on the plot of the projection that can be used to overlay planimetry so as to reduce interference. Deletion has the additional advantage that the time required to plot the projection is reduced.

Included as appendices to this report are examples of plots produced by the OBLQMP (oblique map) program resulting from this research and an OBLQMP user's manual.

OBLIQUE PROJECTIONS

Problem Statement. This section addresses the problem of generalization of the existing, highly efficient oblique projection algorithm to provide the capability for generating plots with a continuous range of viewing angles since the existing algorithm only allows viewing angles of $+45^{\circ}$, 0° , and -45° . This problem will be approached by first presenting the derivation of the transformation equations for the oblique projection, then showing the previously developed, high efficiency algorithm.

Motivation for Research. As mentioned earlier, the oblique projection plots produced by the previously developed software were restricted to a limited range of discrete values for the projection angle. While this allowed for a great variety of views, this restriction made generation of arbitrary, often more desirable, projection angles impossible and also inhibited the generation of successive, near-continuous transition views. It was the objective of this research to extend the original algorithm to include these capabilities. It was understood that these modifications would necessarily degrade the algorithm's efficiency, but efforts would be directed toward minimizing the increases of computation time. The modified algorithm sought should be cost effective with respect to computer time.

Definition of an Oblique Projection.² An oblique projection is a pseudo-perspective projection of an object maintaining a constant scale along the axes of the object projected. Within a plane being projected, the oblique projection uniformly transforms angles. The oblique projection is thus a representation preserving quantitative data, and yet is a realistic, pseudo, three-dimensional representation of the object. For these reasons, the oblique projection has been used as a tool of the draftsman.

More precisely, an oblique projection is created when parallel rays or projectors from the object being projected intersect the image or projection plane at an angle other than 90° (see figure 1). Thus, rays from surface planes of the object parallel to the projection plane are imaged in true size and shape. The height and length of the object form a right angle in the object and also form a right angle in the image plane; they are labeled the y- and z-axes in figure 1. The receding axis (length on the x-axis) may be portrayed at any angle between 0° and $\pm 180^{\circ}$ with respect to the y-axis. The scale of the x-axis of the image is dependent on the angle the projectors make with the image plane. The oblique projection thus maintains

² Rising, James S. and Maurice W. Almfeltdt, Engineering Graphics, Wm. C. Brown Book Co., 3d Edition, Copyright 1953, Library of Congress Catalog No. 64-20045, pages 105-109.

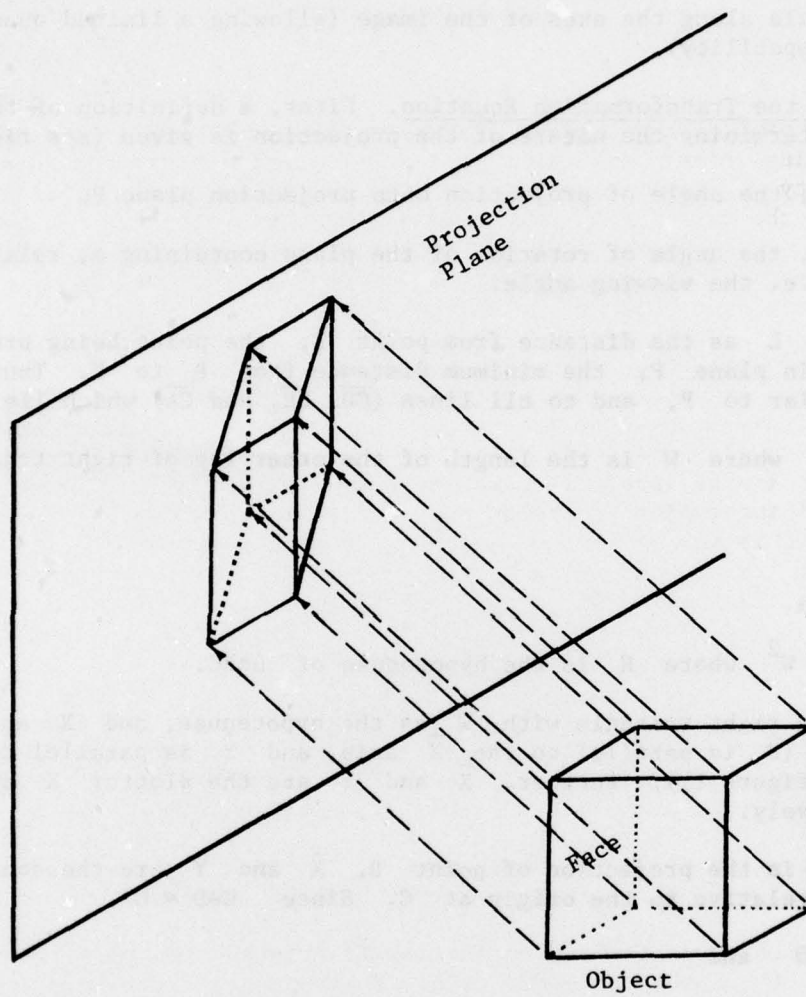


Figure 1. The Oblique Projection

a constant scale along the axes of the image (allowing a limited quantitative mensuration capability).

Derivation of the Transformation Equation. First, a definition of the two parameters determining the nature of the projection is given (see figure 2).

α is BAC, the angle of projection onto projection plane P.

θ is ECA, the angle of rotation of the plane containing α , relative to the y-axis; i.e. the viewing angle.

We define L as the distance from point B, the point being projected, to point C in plane P, the minimum distance from B to P. Thus, L is perpendicular to P, and to all lines (\overline{CD} , \overline{CE} , and \overline{CA}) which lie in P.

$\tan \alpha = \frac{L}{W}$ where W is the length of the other leg of right triangle $\triangle ABC$.

Thus,

$$W = L \cot \alpha \quad (1)$$

$$H = \sqrt{L^2 + W^2} \quad \text{where H is the hypotenuse of } \triangle ABC. \quad (2)$$

$\triangle ACD$ is a right triangle with W as the hypotenuse, and \hat{X} and \hat{Y} as the legs. (\hat{X} is parallel to the \underline{X} axis, and \hat{Y} is parallel to the \underline{Y} axis (see figure 1)). Further, \underline{X} and \underline{Y} are the plotter X and Y area respectively.

Since A is the projection of point B, \hat{X} and \hat{Y} are the coordinates (\bar{X}, \bar{Y}) of A relative to the origin at C. Since $\angle CAD = \theta$

$$\hat{X} = W \sin \theta \quad \text{and}$$

$$\hat{Y} = W \cos \theta. \quad (3)$$

Combining (1), (2), and (3), we have the transformation from the (X,Y,Z) coordinates of a point B to the (\bar{X}, \bar{Y}) coordinates of its projection, A, relative to the perpendicular projection of B to P, C:

$$\bar{X} = L \cot \alpha \sin \theta, \quad (4)$$

$$\bar{Y} = L \cot \alpha \cos \theta \quad (5)$$

For a point B', not at the origin of the (X,Y,Z) coordinate system, (4) and (5) are transformed to

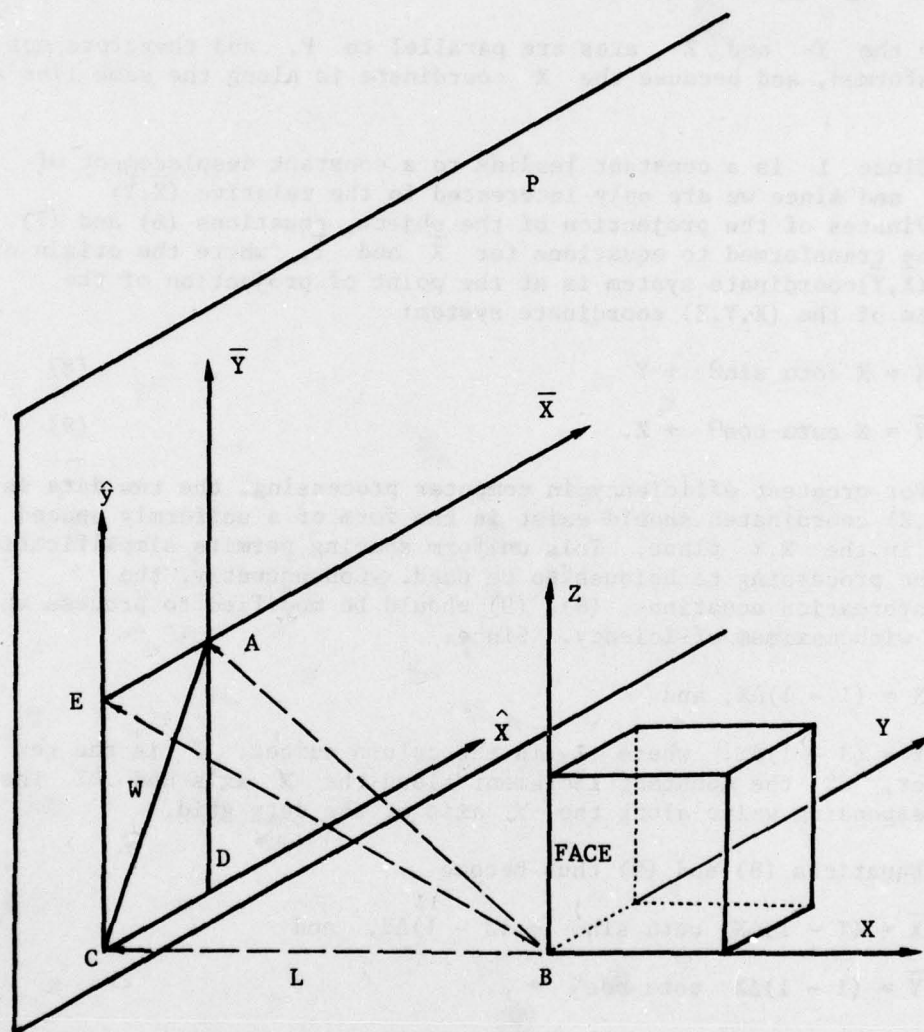


Figure 2. Parameter Definition for Oblique Projections

$$\bar{X} = (L + X) \cot \alpha \sin \theta + Y, \quad (6)$$

$$\bar{Y} = (L + X) \cot \alpha \cos \theta + Z \quad (7)$$

since the Y- and Z- axes are parallel to P, and therefore not transformed, and because the X coordinate is along the same line as L.

Since L is a constant leading to a constant displacement of \bar{X}, \bar{Y} , and since we are only interested in the relative (\bar{X}, \bar{Y}) coordinates of the projection of the object, equations (6) and (7) can be transformed to equations for \bar{X} and \bar{Y} , where the origin of the (X, Y) coordinate system is at the point of projection of the origin of the (X, Y, Z) coordinate system:

$$\bar{X} = X \cot \alpha \sin \theta + Y \quad (8)$$

$$\bar{Y} = X \cot \alpha \cos \theta + Z. \quad (9)$$

For greatest efficiency in computer processing, the raw data in (X, Y, Z) coordinates should exist in the form of a uniformly spaced grid in the X,Y plane. This uniform spacing permits simplification of the processing techniques to be used. Consequently, the transformation equations, (8), (9) should be modified to process the data with maximum efficiency. Since

$$X = (I - 1)\Delta X, \text{ and}$$

$Y = (J - 1)\Delta Y$, where I is the column number, J is the row number, ΔX the constant increment along the X axis and ΔY the corresponding value along the Y axis of the data grid.

Equations (8) and (9) thus become

$$\bar{X} = (I - 1)\Delta X \cot \alpha \sin \theta + (J - 1)\Delta Y, \text{ and}$$

$$\bar{Y} = (I - 1)\Delta X \cot \alpha \cos \theta + Z.$$

Since for most gridded data we may assume that

$\Delta X = \Delta Y$, and for processing efficiency can determine constants for the data set

$$DX = \cot \alpha \sin \theta \Delta X \text{ and}$$

$$DY = \cot \alpha \cos \theta \Delta Y$$

Equations (8) and (9) thus become, for uniformly gridded data

$$\bar{X} = (I - 1)DX + (J - 1)DY, \text{ and}$$

$$\bar{Y} = (I - 1)DX + Z.$$

Thus, by utilizing uniformly spaced elevation data, a great processing efficiency can be realized (see figure 3).

Previous Approaches to the Problem.

Background. One approach to produce oblique projections, an "analytical approach", would produce the projection directly from the transformation equations. This approach suffers in that the algorithm detecting hidden lines is extremely complex and therefore computationally inefficient. Another approach, the one previously developed at ETL, is the "discrete approach." It is limited to the discrete viewing angles of 45° , 0° , or -45° . The advantage of this approach has been proven to be that the hidden line algorithm is extremely efficient.

The Analytical Approach. This is the approach initially taken by the author in attempting to modify and extend the previously developed "discrete approach." Although the hidden line algorithm is simpler than the algorithm used for true perspective views, it is still unsatisfactory in terms of efficient use of computer time.

The fundamental characteristics of this algorithm are the projection of the actual data points using the full transformation equations and the computation of hidden lines using these data points. The hidden line problem becomes significant because the points in the projected array do not "line up" along the \bar{Y} axis (see figure 4). Consequently, any given line segment may intersect any of several previously drawn segments, and a single segment may become hidden and then reappear. Further problems exist in maintaining previous maximum profiles. Although such an algorithm can be created and can be modified to a true perspective view, it is extremely time consuming. At this time, the inefficiency of this approach cannot offer sufficient advantages as a supplement to more standard terrain displays for most uses.

The Discrete Approach. This approach derives its computational efficiency from the projection of the points of the uniformly gridded data in such a manner that the points in the projection plane are aligned parallel to the \bar{Y} axis (see figure 5). Consequently, the hidden line algorithm becomes simple: any given line segment can intersect only one other line segment, and that only once. The problem of determining the point of intersection becomes much simpler--hence the computational efficiency. Unfortunately, the

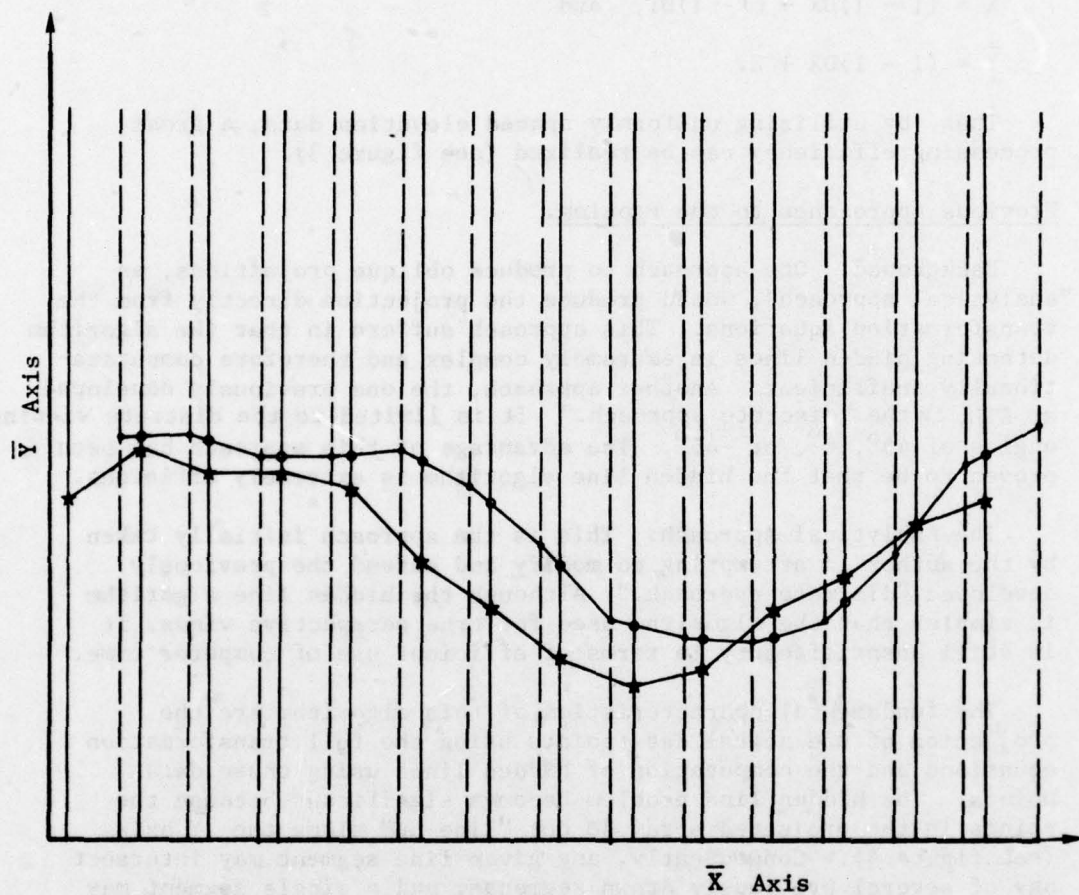


Figure 3. Geometry of the Oblique Projection in the Viewing Plane.

- ★-points of previous profile
- points of current profile
- points to be interpolated

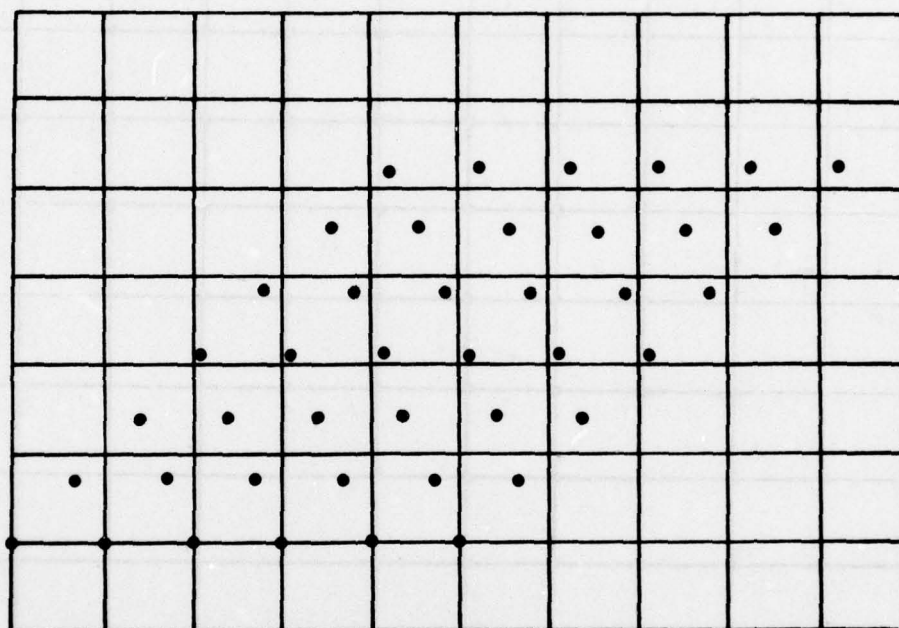


Figure 4. Array of Points of Same Elevation
in Analytical Oblique Projection.

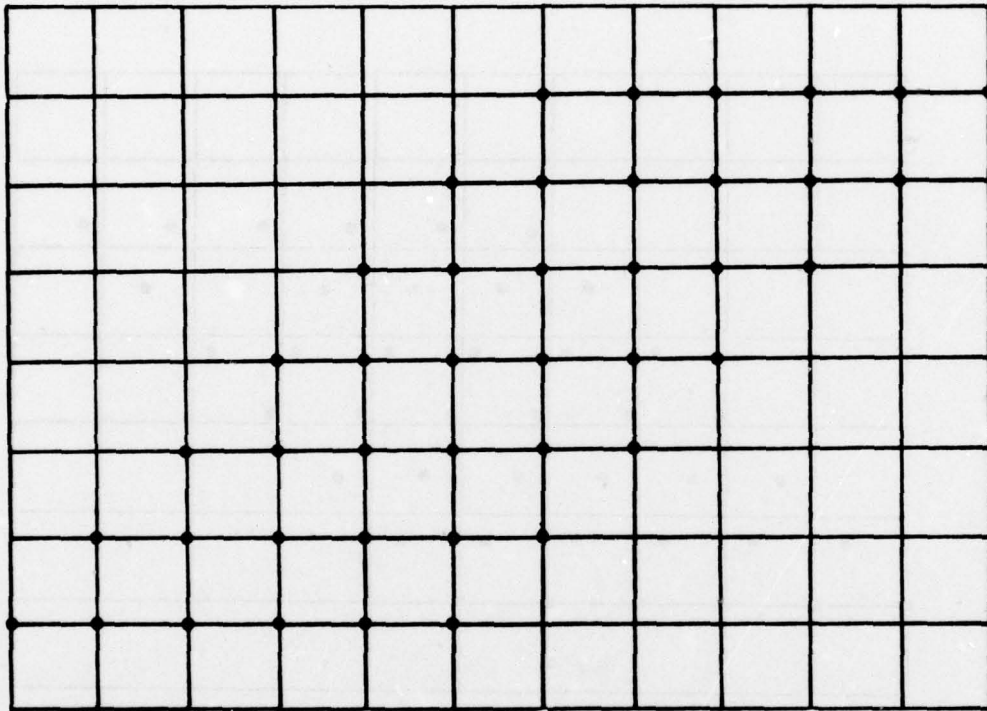


Figure 5. Array of Points of Same Elevation
in Discrete Oblique Projection.

discrete approach is limited to viewing angles of 45° , 0° , and -45° -- those angles that result in a regular array. Limited variation prohibits using the discrete approach to obtain oblique projections with arbitrary viewing and projection angles without some modification.

The Modified Oblique Projection. The modified projection combines the versatility of the analytical projection with the efficiency of the discrete projection. The result is an algorithm that cost effectively serves as a supplement to traditional terrain representations for many purposes.

The combination of the computational efficiency advantages and the arbitrary projection angles is achieved by the following solution suggested by Mr. Jancaitis: estimate the elevations of the profile lines at those locations allowing simplicity in the hidden line algorithm, through linear interpolation. This would be a preferable extension of the discrete approach, since it allows efficiency and versatility in the algorithm.

A more rigorous explanation may be necessary for clarity. We begin by examining the aspects of the discrete oblique projection, which leads to its computational efficiency. This efficiency is derived from points on succeeding profiles in the projection that lie in a regular array with projected data points lying along a line parallel to the Y axis of the projection plane, with successive lines uniformly spaced along the X axis. Consequently, it is easy to store the maximum previous profile in an array, updating it with each new profile by comparing the Y value of a point with the previous maximum Y value in the corresponding array position. Thus, a given line segment between any two successive points on a given profile can only intersect a previous profile one time, and then only with the line segment defined by the corresponding Y value in the maximum profile array. Searching for, and computation of, the intersection points then becomes a simpler procedure.

The discrete oblique is limited to those projections in which the actual data points of successive profiles line up with the transformation equations. It is obvious, however, that if the data points could be aligned the hidden lines for any oblique projection could be produced. This can easily be done by interpolating \bar{Y} values at the \bar{X} coordinate of the previous profile. This is the key to a successful synthesis of the two approaches. Mr. Jancaitis' idea has been implemented in the THREED software by using the following modifications.

Three modifications of the gridded data must be made to prepare it in a usable form:

1. The vertical increment (assuming $DY = DX$ in an orthographic

projection) $DY = \cot\alpha \cos\theta DX$, where α is the projection angle and θ is the viewing angle.

2. The initial and final points are plotted in their true position (although these segments are plotted in their actual projected location, they still can only intercept one other line segment because they are end points).

3. Intermediate \bar{Y} values are interpolated at \bar{X} values which have previously been plotted (i.e. in a regular array) as follows (see figure 6):

$$Y' = (\bar{Y}(IU+1) - \bar{Y}(IU)) (\text{fraction}((\cot\alpha \sin\theta) (IU-1))) + Y(I),$$

where

\bar{Y}' is the interpolated value

I is the index of the current point

IU is the profile number

is constant, and any set of relative scales between the receding axis, the vertical axis, and the horizontal axis can be created, allowing approximation of any perspective view (within program limitations) and thus allowing simplified qualitative and quantitative analysis of the projected topography relative to either a true perspective or to other forms of terrain representation. In comparison with the discrete oblique projection, far more continuously varying views are possible, since the full range of viewing angles are possible.

Results. The modified oblique projection algorithm described in the preceeding section has been implemented in the FORTRAN IV program, OBLQMP. This program is capable of producing continuously varying oblique projections, each uniquely defined by six input parameters. At the same time, a significant reduction in execution time is realized, relative to the analytic oblique projection. Table I contains a summary of the views produced, demonstrating the capabilities of the program. Optimum values for the parameters can be found in Appendix II.

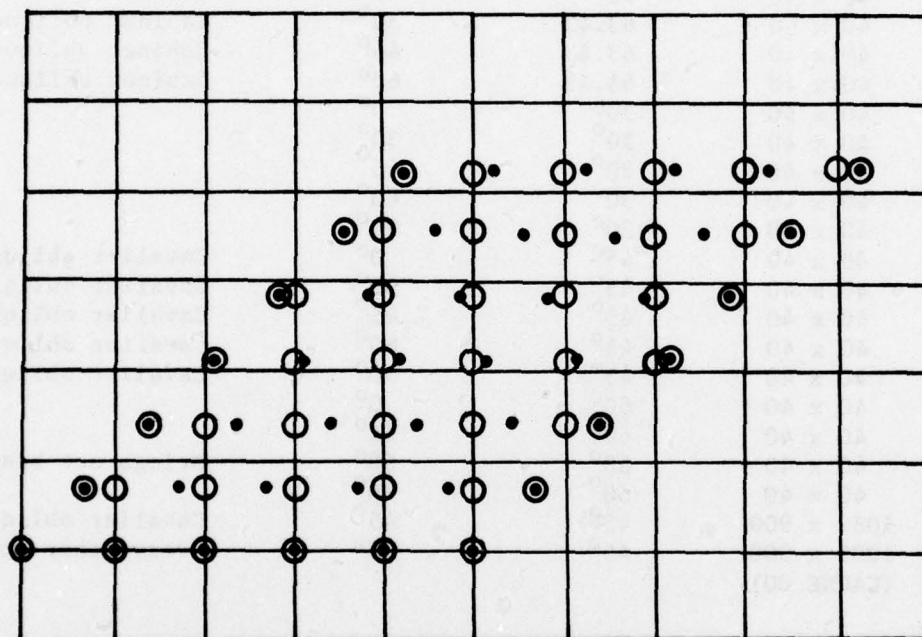


Figure 6. Array of Points of Same Elevation
in Modified and Analytical Oblique
Projections.

- -Analytical Oblique
- -Modified Oblique

Table 1. Significant Data for Oblique
Projections in Appendix 1

<u>FIGURE NUMBER</u>	<u>DATA SET</u>	<u>PROJECTION ANGLE</u>	<u>VIEWING ANGLE</u>	<u>NOTES</u>
1	40 x 40	90°	0°	Shore line view
2	40 x 40	63.43	30°	Cabinet oblique
3	40 x 40	63.43	45°	Cabinet oblique
4	40 x 40	63.43	60°	Cabinet oblique
5	40 x 40	30°	0°	
6	40 x 40	30°	30°	
7	40 x 40	30°	45°	
8	40 x 40	30°	60°	
9	40 x 40	30°	90°	
10	40 x 40	45°	0°	Cavalier oblique
11	40 x 40	45°	30°	Cavalier oblique
12	40 x 40	45°	45°	Cavalier oblique
13	40 x 40	45°	60°	Cavalier oblique
14	40 x 40	45°	90°	Cavalier oblique
15	40 x 40	60°	0°	
16	40 x 40	60°	45°	
17	40 x 40	60°	60°	Brings out base
18	40 x 40	60°	90°	
19	1089 x 900	45°	45°	Cavalier oblique
20	1089 x 900 (CACHE CO)	45°	45°	Every other profile

DELETION OF INSIGNIFICANT LINES

Problem Statement. The problem examined in this section is the deletion of lines in an oblique projection of a topographic surface. The deletion criteria will be to delete those lines that contribute the least information to the oblique projection.

Motivation for Research. The production of oblique projections of topographic surfaces has been hampered by the difficulty involved in overlaying planimetry with sufficient contrast to the background to be clearly visible. Previous analysis of the problem by Mr. Jancaitis at ETL resulted in graphics which support the premise that it is possible to delete portions of the oblique projection and retain the plasticity of the projection. This can result in reduced plot time and increased contrast with overlay planimetry. Implementation of an algorithm deleting insignificant portions of an oblique projection could increase the usefulness and cost effectiveness of the oblique projection of topographic surfaces.

Criteria for Deletion.

Background. Analysis of the problem of defining criteria for insignificance of lines on an oblique projection of topographic surfaces soon leads to the conclusion that this would be best approached in a negative manner. It appears to be easier to define significant portions of an oblique projection, thus establishing any line segment not meeting the criteria of significance as nonessential. The problem thus becomes one of defining criteria for the retention of those portions of an oblique projection that can define the topographic surface projected to an observer.

The definition of criteria for retention of features required examination of the oblique projections of terrain elevation data and the qualitative decision that specific portions of the projection contributed more information to the observer than others. On the basis of those portions of projections identified, criteria for significance were derived. Criteria identified by Mr. Jancaitis in his previous work were sections of profiles that were relative maxima or minima that rapidly changed in slope and that disappeared behind, or were very close to, previous profiles. Sections meeting these criteria seemed to contribute significantly more information to the viewer than other areas. These criteria thus became the basis for the derivation of algorithms retaining only significant portions of the oblique projection.

The algorithms for the various criteria, as implemented in program OBLQMP, have several similarities that should be briefly mentioned. With the algorithms derived for each criteria and after a point has been determined to be significant, a constant number of points (for that criteria)

are plotted in both directions along the current profile. This emphasizes the feature and adds to the impression of plasticity of the projection. In each case, a number of points are also plotted in both directions along the current profile on the basis of slope around the significant point (in the case of change-in-slope, it is on the basis of a change in slope). This makes interpretation of the projection simpler.

Slope-Sign Change. This criterion for retention of features is based on the premise that relative maxima and minima along a profile are significant features of the landscape. By using this criterion, ridges, valleys, and other features can be portrayed that are less significant than might be required by the slope-change detection logic, but that are still an integral part of the topography. To decrease the minimum significance (i.e. slope change) required by the slope-change logic will bring out features that are probably superfluous, from both a qualitative and quantitative viewpoint. Detection of such maxima and minima is particularly important in determining line-of-sight, etc., as well as from a perceptual viewpoint since such detail is necessary to maintain the plasticity of the projection.

More specifically, this criterion determines whether or not, on the basis of N points on either side of the point in question, there is a relative maximum or minimum and whether or not the change in slope around the maximum or minimum point is of sufficient significance to portray the feature. The feature is then depicted by plotting a minimum of M -line segments on either side of the critical point, plus some number of line segments, dependent upon the significance of the feature in terms of slope. The minimum number of points plotted, M , can be varied for perceptual optimization, as can the function, for optimization of the depiction of quantitative information regarding the feature.

The algorithm for this criterion is simple. A search is made through the points of a profile, determining the slope over N points on either side of the current point under consideration. If the sign of the slopes is different, the magnitude of the average slope for both sides is computed. If this quantity is greater than a minimum value, some M -line segments are drawn on either side of the critical point, plus some number of points determined by a linear function of the average slope.

Hidden Lines. This criterion for the retention of certain features is based on the assumption that a profile is significant in the region in which it disappears or reappears, because of some obscuring feature in the foreground. This is perceptually essential if the projection is to appear three-dimensional. If these lines are not plotted, the projection will appear to be flat. Connected with the hidden line criterion is another minor, but necessary, definition. It is essential that the segment behind which a line disappears be plotted. Possibly, this segment of a previous profile has not been considered significant by the other criteria. However, it is necessary to depict it if the projection is to appear realistic. Also,

it is important to note that these criteria for significance are largely of aesthetic importance. The appearance or disappearance of a line is plotted only to emphasize the multi-dimensionality of the projection.

The algorithm proceeds by first making a search through a profile for points that are hidden behind a previous profile. When such a disappearance (or reappearance) is made, some number (a constant) of points are plotted on the visible side of the point of intersection. In addition, further points are plotted on the basis of the slope of the line disappearing or reappearing. As with the change in sign of slope logic, the parameters involved (number of points over which slope is determined) can be varied to optimize the appearance of the plot. It should be noted that even though for most terrain the slope function is insignificant, in some areas it presents significant quantitative information.

Slope Change. This criterion defines as significant those areas of the topography where the slope of a profile is rapidly changing. This is, essentially, a check of the second derivative for rapid changes. Such change is indicative of a change in the nature of the terrain. This criterion thus establishes significant topographic surface areas, such as mountains meeting plains, plateaus, and other rapid changes in slope. Such features would not be defined as significant by the other criteria mentioned, hence the necessity of using it.

The algorithm for implementing this criteria is unique in comparison with the other criteria. Slope is determined over N points in both directions along the profile. The difference in these slopes is computed and checked to determine if it is considered significant. If it is significant, a total of $J + K$ points are plotted in both directions along the profile, where J is a constant and K is an integer determined by a constant times the change in slope. Both J and the constant used to determine the number of additional points to be plotted can be varied to optimize the appearance of and the amount of quantitative data available from the oblique projection plot.

Minimal Spacing. These former criteria, unfortunately, are not adequate to detect the minor undulations in the relatively flat areas. As a partial solution, another criteria was devised based on the assumption that successive profiles of significant features on the plains (such as ridges, valleys, etc.) are more closely spaced than normally. This criteria has relatively little impact upon terrain depiction in mountainous regions, since areas considered significant by this criteria in mountainous regions are likely to be considered significant by the other criteria. This criteria increases the impression of plasticity in the plot of the projection by plotting significant features in "flat" areas.

One value is extremely critical: the maximum spacing to be considered significant. Too large a value results in plotting most of the projection, and too small a value barely highlights the relevant features. The problem

is qualitative: how many lines are adequate? No formula has been derived for optimization of the value over a given terrain.

The algorithm proceeds as follows: As the current profile is scanned, point by point, a comparison is made with corresponding point of the maximum previous profile. If the difference is less than the minimum value, the feature is considered significant. On either side along the current profile N points are plotted, and M points are plotted on either side of the significant point along the current profile. For this criterion, N is a constant and M is the integer resulting from the multiplication of the change in slope by a constant. Optimization of the parameters is of course possible, though somewhat more critical than in the other criteria.

Results. The algorithms described in the preceeding section have been implemented in the FORTRAN IV OBLQMP program. Fifteen input variables read by OBLQMP relate to the deletion criteria and produce the corresponding plots. Time was insufficient to determine the optimum values of the variables, though reasonable bounds can be placed on most. Table 1 contains a summary of the views produced. Perception of the plots varies with viewers. A major problem seems to have been the contrast involved. Nevertheless, most people have relatively little trouble visualizing the topography and qualitatively analyzing the terrain.

While computer time increased for the production of the views, plot time has been reduced when the line deletion logic is used (falling from approximately 4.5 hours for all CACHE data points 1089 to 900 to approximately 3.0 hours for plots of significant points only, figures based on plots with a base of 15 inches). Execution time for OBLQMP has increased by approximately 15 percent over the program without the deletion criteria.

Table 2 summarizes the plots and the significant features that were produced utilizing OBLQMP's line deletion criteria. Time did not permit greater variation of the parameters, or systematic variation of slope-change and disappearing line parameters.

It should be noted that plots 43, 44, 45, and 46 were prepared during the final day of preparation of this report. Plots 43, 45, 46 were found to have Honablew lines (spurious lines of unknown origin). Time was not sufficient to determine their origin or why they were not present on previous plots.

The plots demonstrate the extent to which the various criteria develop, the effect of varying values of the input parameters, and the type of features retained. More importantly, the plots demonstrate the feasibility of deleting portions of the projections while retaining the impression of a continuous topographic surface. However, the results to date, while encouraging, still indicate the need for further work.

Table 2. Data for Oblique Projections
With Line Deletions in
Appendix 1.

<u>PLOT #</u>	<u>DATA SET</u>	<u>DISTINGUISHING FEATURES</u>
21	CACHE	Hidden line, change-in-slope sign implemented
22	CACHE	Change-in-slope implemented
23	CACHE	-Every other profile plotted -# points drawn (minimum) increased from 6 to 10
24	CACHE	-Minimal spacing implemented (min. spacing = 0.9 nominal)
25	CACHE	Min. spacing = 0.3 nominal
26	CACHE	Min. spacing = 0.65 nominal
27	CACHE	Every profile plotted
28	PRTCCH*	Nominal values
29	PRTCCH	I4 = 3
30	PRTCCH	I4 = 9
31	PRTCCH	C2 = 0.175
32	PRTCCH	C2 = 0.375
33	PRTCCH	C3 = 7.5
34	PRTCCH	C3 = 22.5
35	PRTCCH	I5 = 3.0
36	PRTCCH	I5 = 9.0
37	PRTCCH	I6 = 6.0
38	PRTCCH	I6 = 18.0
39	PRTCCH	Closer = 0.3
40	PRTCCH	Closer = 0.9
41	PRTCCH	C7 = 7.5
42	PRTCCH	C7 = 22.5
43	PRTCCH	Slope-sign change only
44	PRTCCH	Minimal spacing only
45	PRTCCH	Disappearing lines only
46	PRTCCH	Slope-change only

NOTE: For a full explanation of variables, refer to Appendix 2.

*PRTCCH = 200 x 250 portion of CACHE

Further Research. Additional areas of work have, on the basis of the present research, become evident. These include either further refining the present software or seeking alternatives to the current approach to the problem of qualitatively representing topography through automated cartographic techniques.

Overlay Planimetry. By overlaying planimetry, two advantages could be achieved over the present software: (1) a more plastic projection when line deletion criteria are used, and (2) a more quantitative and useful projection. It should be noted that the research described previously was undertaken to allow the placement of planimetry on an oblique projection.

Extend the Software to Permit Any View. The current software is limited to oblique projections with projection and viewing angles between 0° and 90° . To adequately portray all of a given elevation data set, greater flexibility is required. This research would be likely to involve new data storage techniques, for example, modeling of the terrain using polynomials as well as modifications to the software.

Optimization of Line Retention Parameters. Time was not available during the present research to investigate extensively the optimum values for the line retention parameters. These optimum values are likely to vary widely with the type of topography, hence the need for research to determine these values. Such research must be conducted for different types of terrain, with varying input parameters (relative scale of the axes, various projection and viewing angles, etc.).

Extend the Hidden Line Algorithm to Perspective Projections. The present research was based on the assumption that the oblique projection was as good as, if not superior to, true perspective projections of topography for many purposes. Nevertheless, for many applications a true perspective view would be desirable. For such purposes the hidden line algorithm can be adapted to true perspective projections with comparable efficiency. This will involve using the transformation equations for a true perspective and subsequent modification of the algorithms described in this report.

Oblique/Perspective Comparison. The oblique projection of large data sets with closely spaced data points derives some of its visual representation of the terrain from the impression of gray shades. This is based on the close, but finite, spacing of successive profiles, giving the impression of viewing the topography with the source of light behind the viewer. It is possible to produce true gray-shade views of topography with arbitrary lighting and viewing directions.³ Appropriate output devices are necessary and generally available.

³Marsik, Z., "Automatic Relief Shading," Photogrammetria, 27 (1971), pages 57-70.

CONCLUSIONS.

The research performed in this report has resulted in two developments:
(1) extension of the discrete hidden-line algorithm to an arbitrary viewing angle for the oblique projection of digital terrain elevation data, and
(2) the deletion of insignificant portions of projections results in significantly reduced plot times and may permit better comprehension of overlaid planimetry.

The OBLIQMP software is one solution to the problem of creating a two-dimensional representation of a three-dimensional surface. It allows both qualitative and quantitative analysis, and is both versatile and efficient.

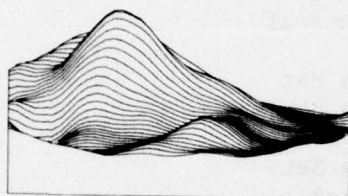
LIST OF PLOTS IN APPENDIX 1.

1. "Shoreline" View of Shiraz, Iran (40 x 40) Data Set
PRJNG = 90.0, VWNG = 0.0
2. Cabinet Oblique Projection of Shiraz Data Set
PRJNG = 63.43, VWNG = 30.0
3. Cabinet Oblique Projection of Shiraz Data Set
PRJNG = 63.43, VWNG = 45.0
4. Cabinet Oblique Projection of Shiraz Data Set
PRJNG = 63.43, VWNG = 60.0
5. General Oblique Projection of Shiraz Data Set
PRJNG = 30.0, VWNG = 0.0
6. General Oblique Projection of Shiraz Data Set
PRJNG = 30.0, VWNG = 30.0
7. General Oblique Projection of Shiraz Data Set
PRJNG = 30.0, VWNG = 45.0
8. General Oblique Projection of Shiraz Data Set
PRJNG = 30.0, VWNG = 60.0
9. General Oblique Projection of Shiraz Data Set
PRJNG = 30.0, VWNG = 90.0
10. Cavalier Oblique Projection of Shiraz Data Set
PRJNG = 45.0, VWNG = 0.0
11. Cavalier Oblique Projection of Shiraz Data Set
PRJNG = 45.0, VWNG = 30.0
12. Cavalier Oblique Projection of Shiraz Data Set
PRJNG = 45.0, VWNG = 45.0
13. Cavalier Oblique Projection of Shiraz Data Set
PRJNG = 45.0, VWNG = 60.0
14. Cavalier Oblique Projection of Shiraz Data Set
PRJNG = 45.0, VWNG = 90.0
15. General Oblique Projection of Shiraz Data Set
PRJNG = 60.0, VWNG = 0.0

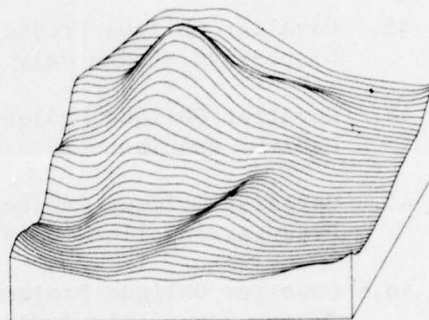
16. General Oblique Projection of Shiraz Data Set
PRJNG = 60.0, VWNG = 45.0
17. General Oblique Projection of Shiraz Data Set, emphasizing the base
PRJNG = 60.0, VWNG = 60.0
18. General Oblique Projection of Shiraz Data Set
PRJNG = 60.0, VWNG = 90.0
19. Cavalier Oblique Projection of CACHE (1084 x 900) Data Set
PRJNG = 45.0, VWNG = 45.0
20. Cavalier Oblique Projection of CACHE Data Set with alternate profiles
deleted
PRJNG = 45.0, VWNG = 45.0, MSKIP = 1
21. Cavalier Oblique Projection of CACHE Data Set with hidden line and
change in slope-sign significance criteria implemented
PRJNG = 45.0, VWNG = 60.0
22. Cavalier Oblique Projection of CACHE Data Set with hidden line, change
in slope-sign, and change in slope significance criteria implemented
PRJNG = 45.0, VWNG = 60.0
23. Cavalier Oblique Projection of CACHE Data Set with hidden line, change
in slope-sign, and change in slope significance criteria implemented;
alternate profiles deleted; minimum number of points plotted increased
from 6 to 10
PRJNG = 45.0, VWNG = 60.0, MSKIP = 1
24. Cavalier Oblique Projection of CACHE Data Set, alternate profiles
deleted; minimal spacing criterion implemented with high value for
CLOSER
PRJNG = 45.0, VWNG = 60.0, MSKIP = 1, CLOSER = 1.8
25. Cavalier Oblique Projection of CACHE Data set, alternate profiles
deleted, with low value of CLOSER near optimum
PRJNG = 45.0, VWNG = 60.0, MSKIP = 1, CLOSER = 0.6
26. Cavalier Oblique Projection of CACHE Data Set, alternate profiles
deleted, CLOSER near optimum
PRJNG = 45.0, VWNG = 60.0, MSKIP = 1, CLOSER = 1.3
27. Cavalier Oblique Projection of CACHE Data Set, all parameters assume
nominal values for this data set
N = 1084, M = 900, DEM = 800.0, S = 15.0, ICODE = 0, NSKIP = 0,
MSKIP = 0, PRJNG = 45.0, VWNG = 60.0, I1 = 15, I4 = 6, C2 = 0.25,
C3 = 15.0, I4 = 6, I6 = 10, CLOSER = 0.6, C7 = 15.0, I8 = 15, I9 = 10,
C10 = 15.0, I11 = 6, I14 = 6, C12 = 0.18, C13 = 15.0

28. Cavalier Oblique Projection of DRTCCN (A 200 x 250 portion of CACHE) Data Set, all parameters assume nominal values for this data set
N = 250, M = 200, DEM = 300.0, S = 5.0, ICODE = 0, NSKIP = 0,
MSKIP = 0, PRJNG = 45.0, VWNG = 60.0, I1 = 15, I4 = 6, C2 = 0.25,
C3 = 15.0, I5 = 6, I6 = 10, CLOSER = 0.6, C7 = 15.0, I8 = 15, I9 = 10,
C10 = 15.0, I11 = 6, I14 = 6, C12 = 0.18, C13 = 15.0
29. Cavalier Oblique Projection of PRTCCH Data Set
I4 = 3; all other parameters assume nominal values
30. Cavalier Oblique Projection of PRTCCH Data Set
I4 = 9; all other parameters assume nominal values
31. Cavalier Oblique Projection of PRTCCH Data Set
C2 = 0.175; all other parameters assume nominal values
32. Cavalier Oblique Projection of PRTCCH Data Set
C2 = 0.375; all other parameters assume nominal values
33. Cavalier Oblique Projection of PRTCCH Data Set
C3 = 7.5; all other parameters assume nominal values
34. Cavalier Oblique Projection of PRTCCH Data Set
C3 = 22.5; all other parameters assume nominal values
35. Cavalier Oblique Projection of PRTCCH Data Set
I5 = 3.0; all other parameters assume nominal values
36. Cavalier Oblique Projection of PRTCCH Data Set
I5 = 9; all other parameters assume nominal values
37. Cavalier Oblique Projection of PRTCCH Data set
I6 = 6; all other parameters assume nominal values
38. Cavalier Oblique Projection of PRTCCH Data Set
I6 = 18; all other parameters assume nominal values
39. Cavalier Oblique Projection of PRTCCH Data Set
CLOSER = 0.3; all other parameters assume nominal values
40. Cavalier Oblique Projection of PRTCCH Data Set
CLOSER = 0.9; all other parameters assume nominal values
41. Cavalier Oblique Projection of PRTCCH Data Set
C7 = 22.5; all other parameters assume nominal values
42. Cavalier Oblique Projection of PRTCCH Data Set
C7 = 22.5; all other parameters assume nominal values

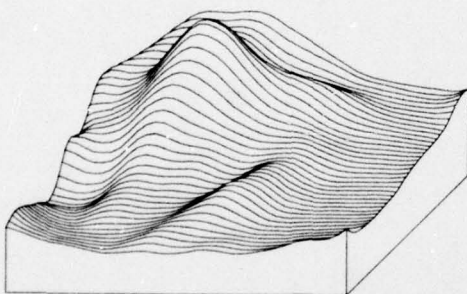
- 43. Cavalier Oblique Projection of PRTCCH Data Set
Slope-sign change only - Parameter values nominal
- 44. Cavalier Oblique Projection of PRTCCH Data Set
Minimal spacing only - parameter values nominal
- 45. Cavalier Oblique Projection of PRTCCH Data Set
Disappearing lines only - parameter values nominal
- 46. Cavalier Oblique Projection of PRTCCH Data Set
Slope-change only - parameter values nominal



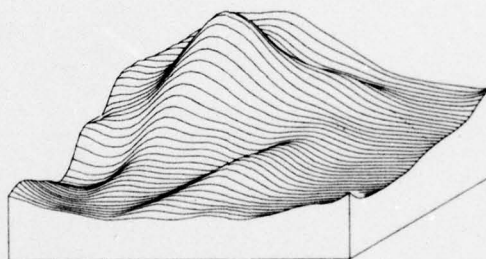
1. "SHORELINE" VIEW OF SHIRAZ, IRAN (40 x 40) DATA SET
PRJNG = 90.0, VWNG = 0.0



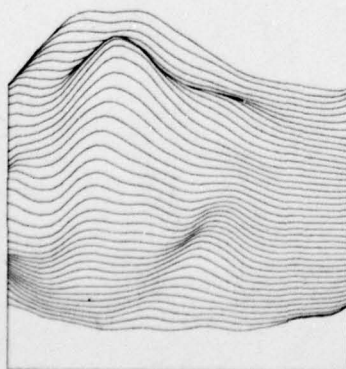
2. CABINET OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 63.43, VWNG = 30.0



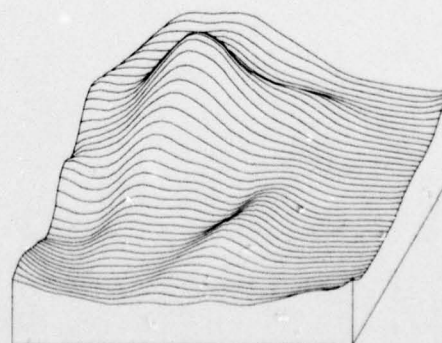
3. CABINET OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 63.43, VWNG = 45.0



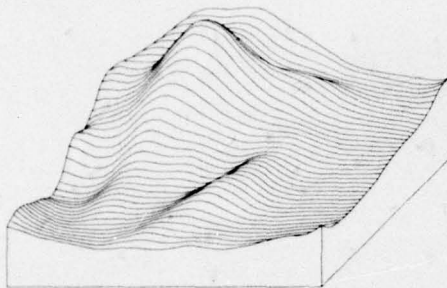
4. CABINET OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 63.43, VWNG = 60.0



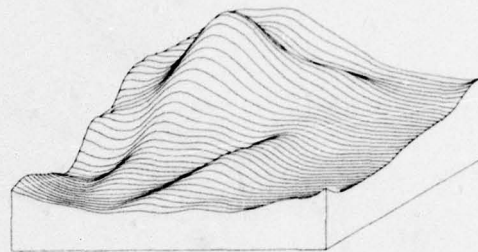
5. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 60.0, VWNG = 0.0



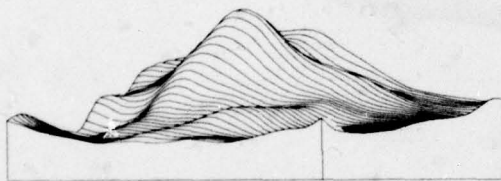
6. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 60.0, VWNG = 30.0



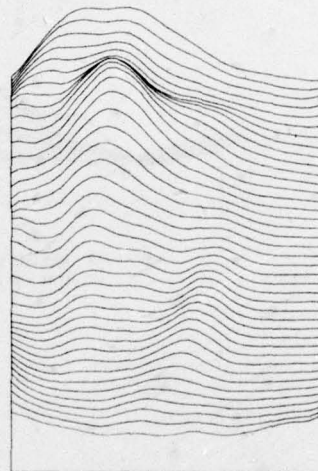
7. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 60.0, VWNG = 45.0



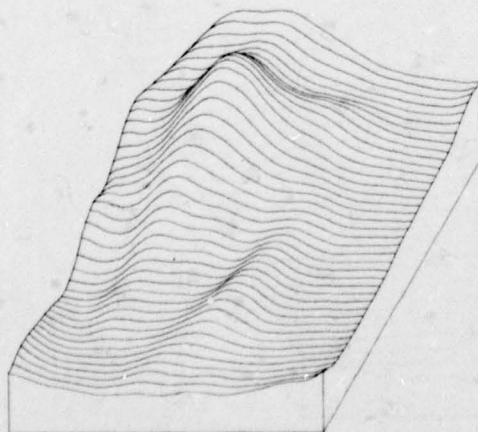
8. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 60.0, VWNG = 60.0



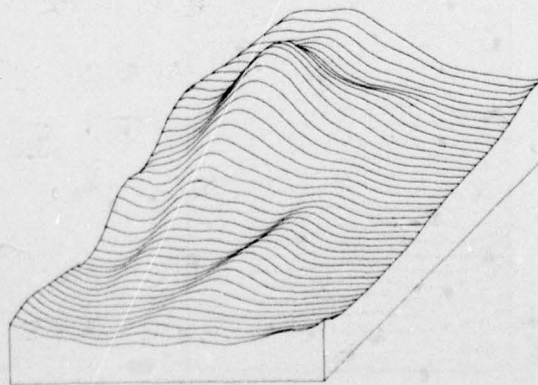
9. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 60.0, VWNG = 90.0



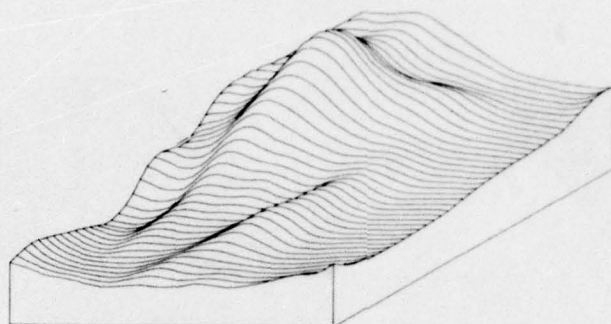
10. CAVALIER OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 45.0, VWNG = 0.0



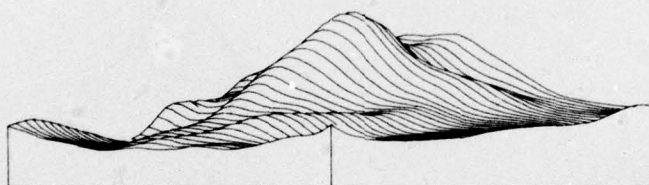
11. CAVALIER OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 45.9, VWNG = 30.0



12. CAVALIER OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 45.0, VWNG = 45.0



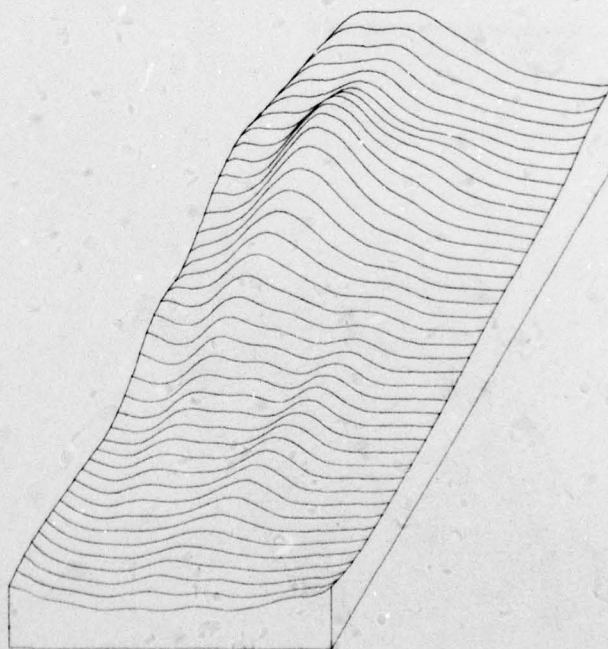
13. CAVALIER OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 45.0, VNG = 60.0



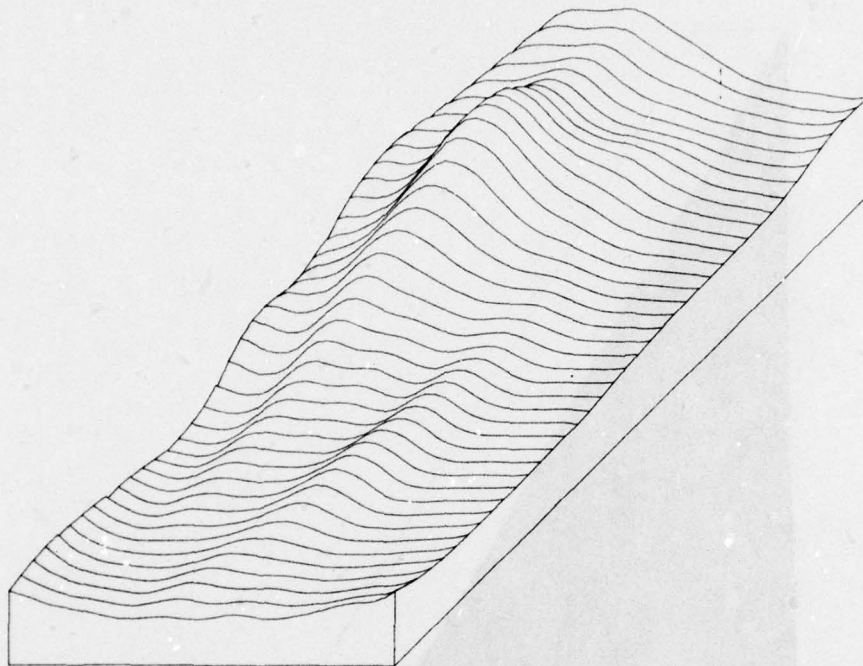
14. CAVALIER OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 45.0, VNG = 90.0



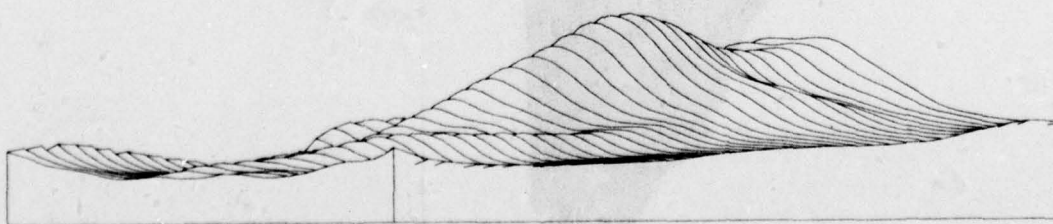
15. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 30.0, VNG = 0.0



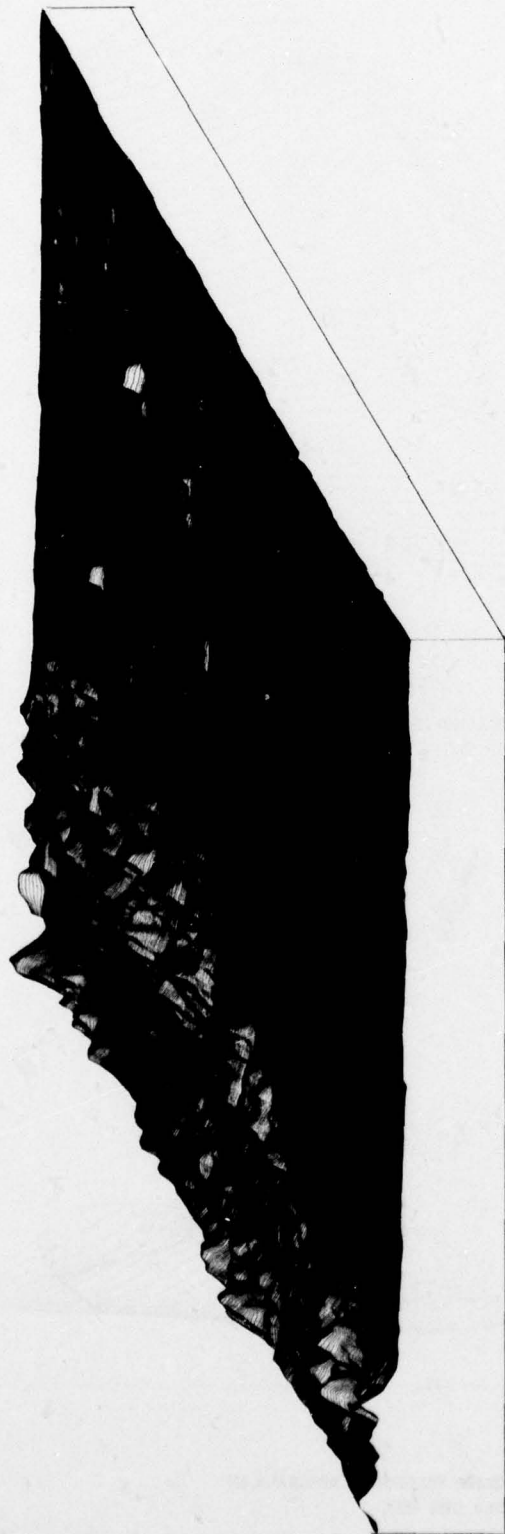
16. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET
PRJNG = 30.0, VNG = 45.0



17. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET, EMPHASIZING THE BASE
 PRJNG = 30.0, VWNG = 60.0



18. GENERAL OBLIQUE PROJECTION OF SHIRAZ DATA SET
 PRJNG = 30.0, VWNG = 90.0



19. COMPUTER OBLIQUE PROJECTION OF CAFFE (1284 x 900) DATA SET
PRNG = 45.0, VIEW = 45.0



20. CAVALIER OBLIQUE PROJECTION OF CACHE DATA SET WITH ALTERNATE PROFILES DELETED
PRJNG = 45.0, VWD = 45.0, MSKIP = 1



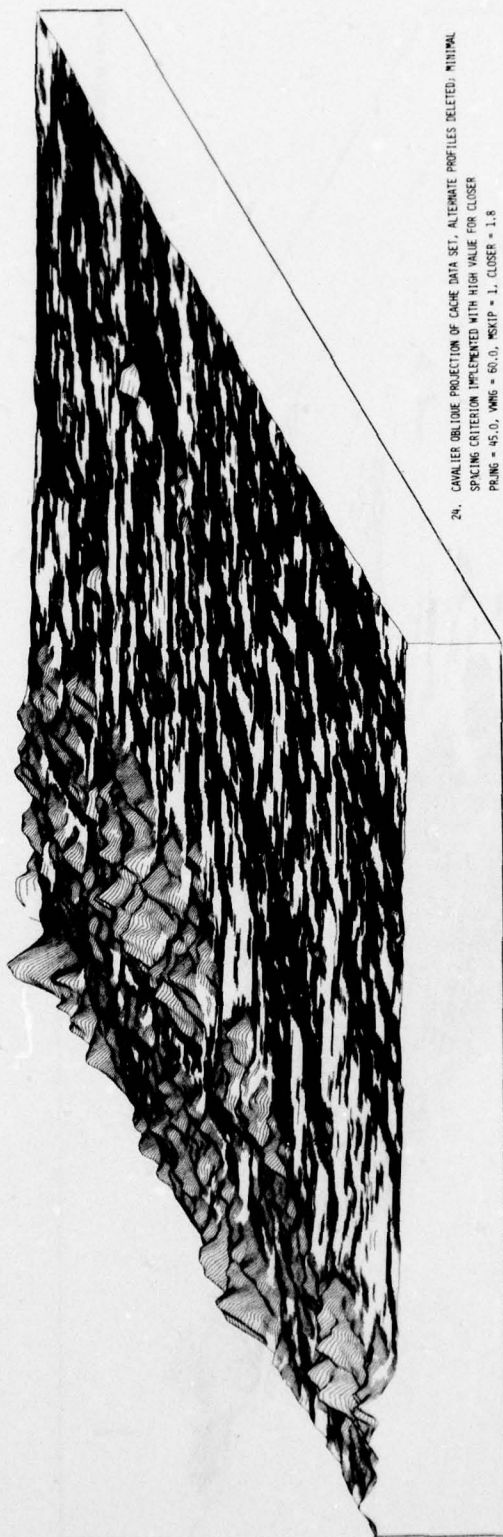
21. CAVALIER OBLIQUE PROJECTION OF CACHE DATA SET WITH HIDDEN LINE AND CHANGE IN
SLOPE-SIGN SIGNIFICANCE CRITERIA IMPLEMENTED
PRJNG = 45.0, VNG = 60.0



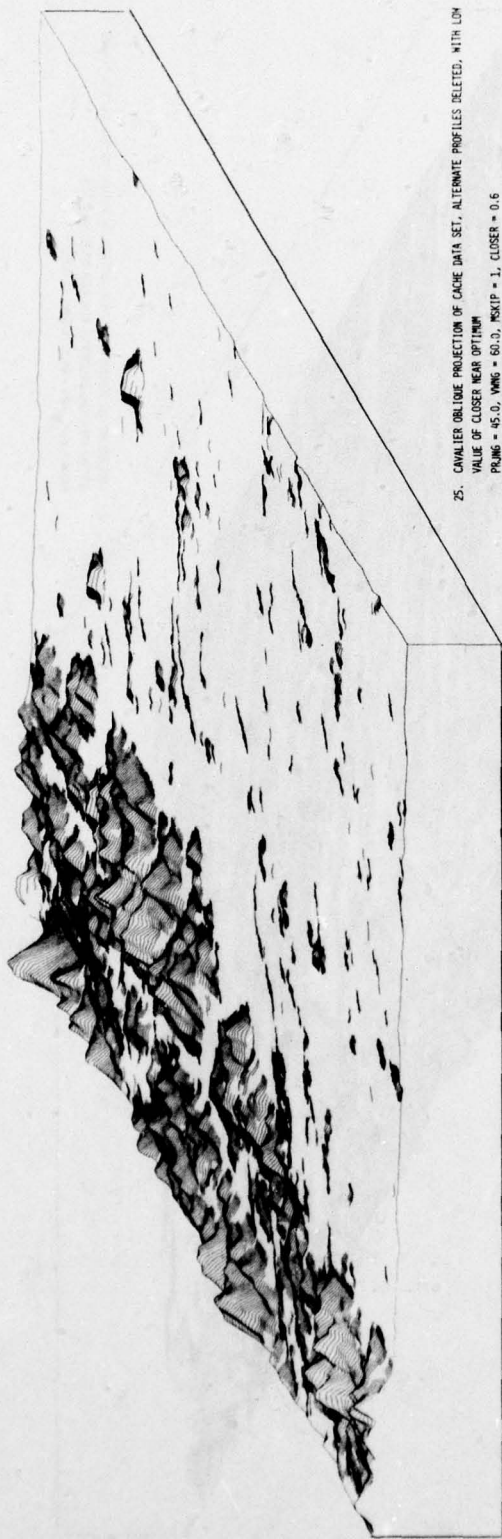
22. CAVALIER OBLIQUE PROJECTION OF CACHE DATA SET WITH HIDDEN LINE, CHANGE IN SLOPE-SEA,
AND CHANGE IN SLOPE SIGNIFICANCE CRITERIA IMPLEMENTED
PRNG = 45.0, RWG = 60.0



25. CAVALIER OBLIQUE PROJECTION OF CACHE DATA SET WITH HIDDEN LINE. CHANGE IN SLOPE-SEN,
AND CHANGE IN SLOPE SIGNIFICANCE CRITERIA IMPLEMENTED, ALTERNATE PROFILES DELETED.
MINIMUM NUMBER OF POINTS PLOTTED INCREASED FROM 6 TO 10
PANG = 45.0, WING = 60.0, NSSIP = 1



24. CAVALIER OBLIQUE PROJECTION OF CACHE DATA SET. ALTERNATE PROFILES DELETED. MINIMAL
SPACING CRITERION IMPLEMENTED WITH HIGH VALUE FOR CLOSER
PRNG = 45.0, WMS = 60.0, MSXP = 1, CLOSER = 1.8



25. CAVALIER OBLIQUE PROJECTION OF CACHE DATA SET, ALTERNATE PROFILES SELECTED, WITH LOW
 VALUE OF CLOSER NEAR OPTIMUM
 PRUNE = 45.0, WING = 60.0, MSKIP = 1, CLOSER = 0.6



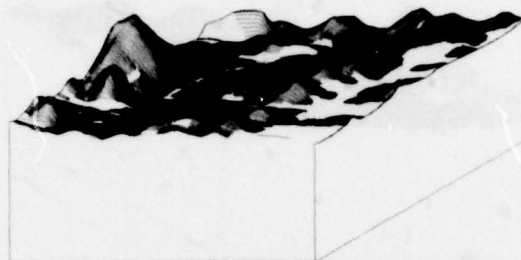
26. CAVALIER OBLIQUE PROJECTION OF CACHE DATA SET, ALTERNATE PROFILES DELETED, CLOSER

NEAR OPTIMUM

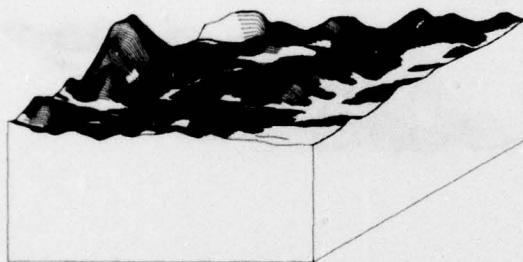
PLNG = 45.0, VNG = 60.0, MSIP = 1, CLOSER = 1.5



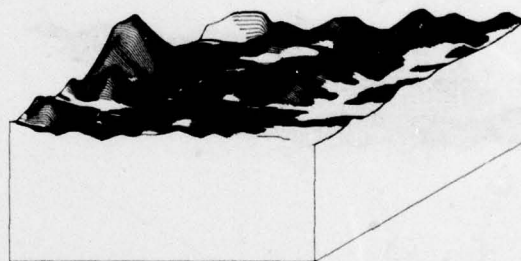
27. CAVALIER OBLIQUE PROJECTION OF CACHE DATA SET, ALL PARAMETERS ASSUME NOMINAL VALUES FOR THIS DATA SET
 N = 1084, M = 900, SEP = 800.0, S = 15.0, ICODE = 0, NSHIP = 0, NSHIP = 0, PRNG = 45.0,
 VNG = 60.0, I1 = 15, I4 = 6, C2 = 0.25, C3 = 15.0, I4 = 6, I6 = 10, CLOSER = 0.6, C7 = 16.0
 I8 = 15, I9 = 10, C10 = 15.0, I11 = 6, I14 = 6, C12 = 0.18, C13 = 15.0



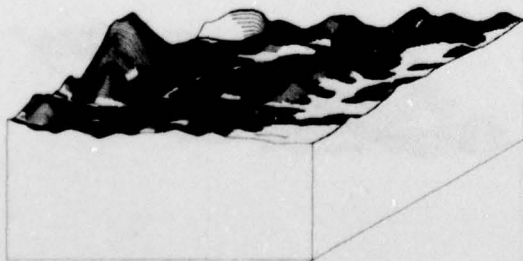
28. CAVALIER OBLIQUE PROJECTION OF DRTCCN (A 200 x 250 PORTION OF CACHE) DATA SET, ALL PARAMETERS ASSUME NOMINAL VALUES FOR THIS DATA SET
 $N = 250$, $M = 200$, $DEM = 300.0$, $S = 5.0$, $ICODE = 0$, $NSKIP = 0$, $MSKIP = 0$, $PRJNG = 45.0$,
 $VWNG = 60.0$, $I1 = 15$, $I4 = 6$, $C2 = 0.25$, $C3 = 15.0$, $I5 = 6$, $I6 = 10$, $CLOSER = 0.6$, $C7 = 15.0$
 $I8 = 15$, $I9 = 10$, $C10 = 15.0$, $I11 = 6$, $I14 = 6$, $C12 = 0.18$, $C13 = 15.0$



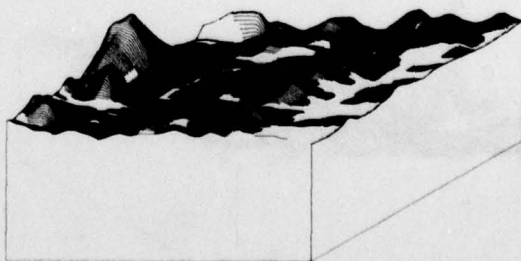
29. CAVALIER OBLIQUE PROJECTION OF PRTCCH DATA SET
 $I4 = 3$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



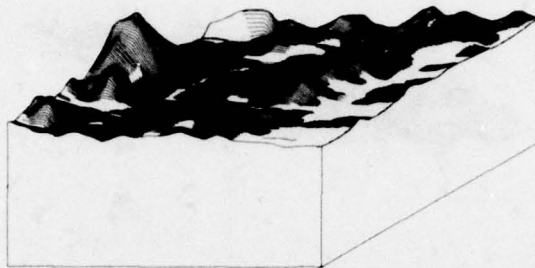
30. CAVALIER OBLIQUE PROJECTION OF PRTCCH DATA SET
 $I4 = 9$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



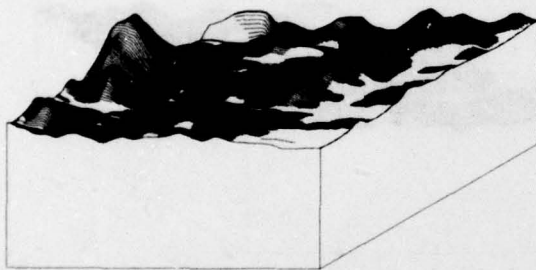
31. CAVALIER OBLIQUE PROJECTION OF PRTCCH DATA SET
 $C2 = 0.175$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



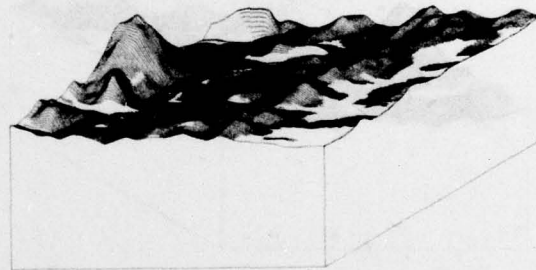
32. CAVALIER OBLIQUE PROJECTION OF PRTCCH DATA SET
 $C2 = 0.375$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



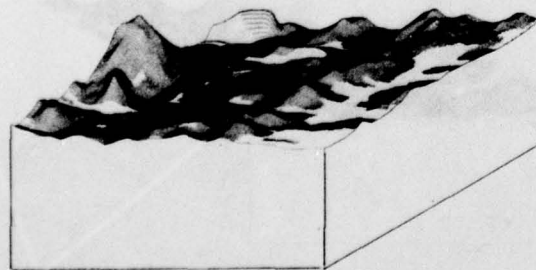
33. CAVALIER OBLIQUE PROJECTION OF PRTCH DATA SET
C3 = 7.5; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



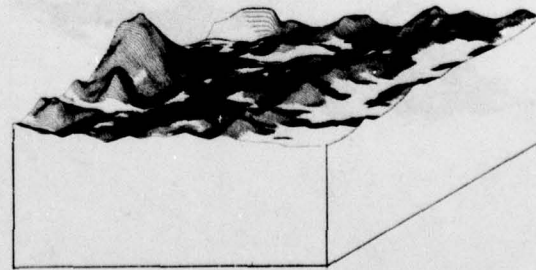
34. CAVALIER OBLIQUE PROJECTION OF PRTCH DATA SET
C3 = 22.5; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



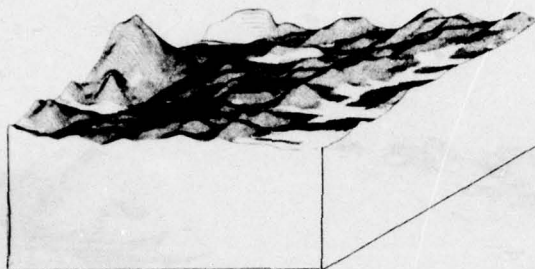
35. CAVALIER OBLIQUE PROJECTION OF PRTCH DATA SET
I5 = 3.0; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



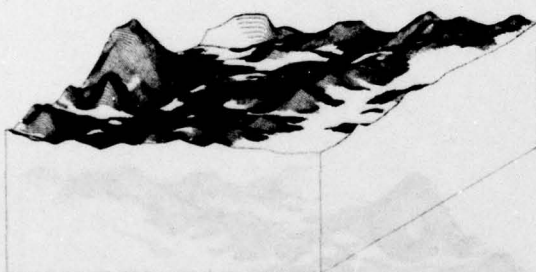
36. CAVALIER OBLIQUE PROJECTION OF PRTCH DATA SET
I5 = 9; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



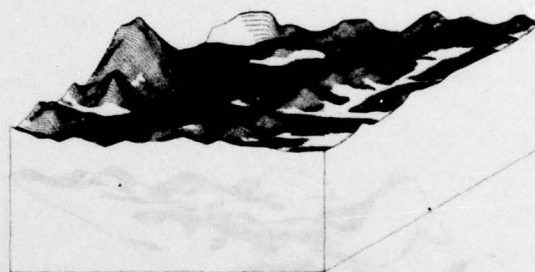
37. CAVALIER OBLIQUE PROJECTION OF PRTCH DATA SET
I6 = 6; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



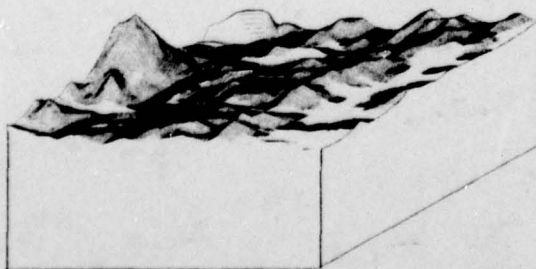
38. CAVALIER OBLIQUE PROJECTION OF PRTOCH DATA SET
 $16 = 18$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



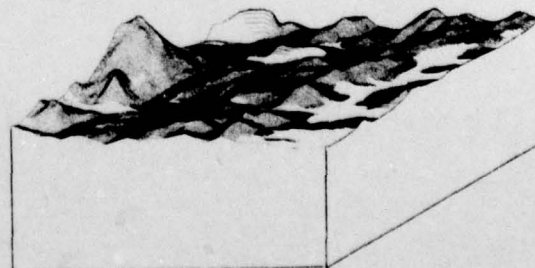
39. CAVALIER OBLIQUE PROJECTION OF PRTOCH DATA SET
 $CLOSER = 0.3$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



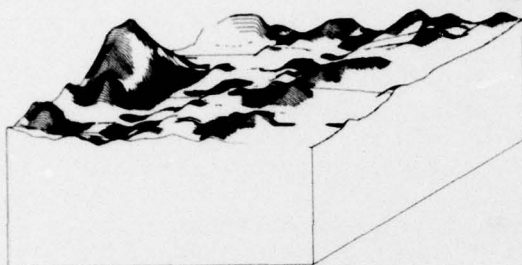
40. CAVALIER OBLIQUE PROJECTION OF PRTOCH DATA SET
 $CLOSER = 0.9$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



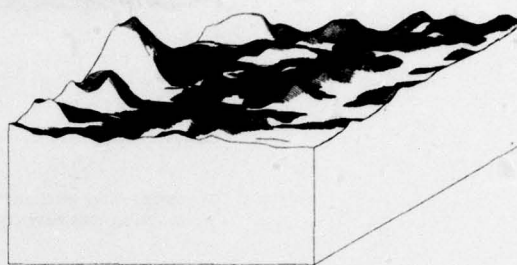
41. CAVALIER OBLIQUE PROJECTION OF PRTOCH DATA SET
 $C7 = 22.5$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



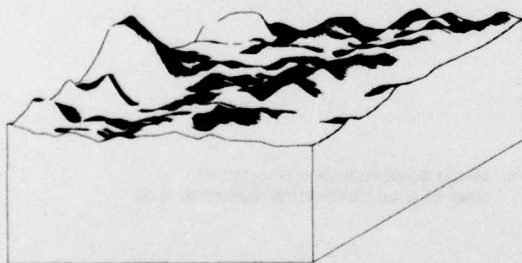
42. CAVALIER OBLIQUE PROJECTION OF PRTOCH DATA SET
 $C7 = 22.5$; ALL OTHER PARAMETERS ASSUME NOMINAL VALUES



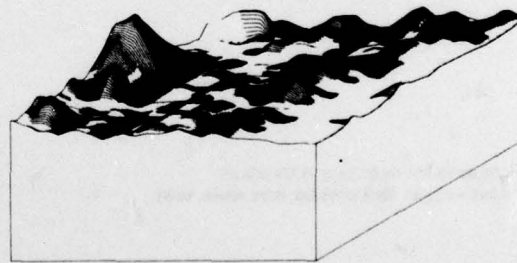
43. CAVALIER OBLIQUE PROJECTION OF PRITCH DATA SET
SLOPE-LINE CHANGE ONLY - PARAMETER VALUES NOMINAL



44. CAVALIER OBLIQUE PROJECTION OF PRITCH DATA SET
MINIMAL SPACING ONLY - PARAMETER VALUES NOMINAL



45. CAVALIER OBLIQUE PROJECTION OF PRITCH DATA SET
DISAPPEARING LINES ONLY - PARAMETER VALUES NOMINAL



46. CAVALIER OBLIQUE PROJECTION OF PRITCH DATA SET
SLOPE-CHANGE ONLY - PARAMETER VALUES NOMINAL

APPENDIX 2. OBLQMP USER'S GUIDE

Introduction.

The OBLQMP is a computationally efficient FORTRAN software system for the production of oblique projections of topographic surfaces from a grid of digital terrain elevation data bases. The software has been produced to run on a CDC 6400 digital computer with the Scope 3.4 operating system.

The OBLQMP software has the following general characteristics:

1. It accepts as input a smoothed elevation data file in sequential profile format previously produced by CONSAC II software.
2. It produces a standard Calcomp plot tape containing an oblique projection of the area.
3. It produces a line printer output of input parameters and internally calculated dependent variables.
4. It allows the user to create an oblique projection of the elevation data for a user-specified projection angle and viewing angle.
5. It allows processing of only user-specified subsets of the input elevation data.
6. It allows for processing only certain user-specified topographic features.
7. It allows the user to determine the size of the projection plot.

The following sections contain the information pertinent to the successful application of the OBLQMP software for the above described products.

Required Input Parameters.

Summary of Input Parameters and Formats. The OBLQMP software requires seven input data cards. The parameters on each card and the input formats are as follows:

-CARD 1 - (Data and Scale Parameters).

N, M, DEM, S

FORMAT 1

8887 Format (2I5, F7.2, F8.4)

-CARD 2 - (Plot and Data Subset Parameters)

ICODE, MSKIP, NSKIP

FORMAT 2.

1 Format (4I4)

-CARD 3 - (Data Transformation Parameters)

PRJNG, VWNG

FORMAT 3.

501 FORMAT (2F8.3)

-CARD 4 - (Slope Sign-Change Retention Parameters)

I1, I4, C2, C3

FORMAT 4.

625 Format (2I3, 2F7.3)

-CARD 5 - (Minimal Spacing Retention Parameters)

I5, I6, CLOSER, C7

FORMAT 5.

625 Format (2I3, 2F7.3)

-CARD 6 - (Disappearing Line Retention Parameters)

I8, I9, C10, C20

FORMAT 6.

625 Format (2I3, 2F7.3)

-CARD 7 - (Slope-Change Retention Parameters)

I11, I14, C12, C13

FORMAT 7.

625 Format (2I3, 2F7.3)

Detailed Explanation of Parameters. The nominal value of each parameter is contained in the parenthesis immediately following the parameter. The detailed explanation of parameters is as follows (in order of appearance of data cards):

-CARD 1 - Input Parameters

NOTE: Card 1 input parameters may be input only once. These may not be varied for multiple plots produced during a single execution.

N; (1089) - the integer number of points per profile contained on the input-smoothed elevation data. If the number is not known, any integer may be input as long as it is less than or equal to the actual value. This will omit some of the data. Values larger than the actual value will leave a border of 0 elevations on one side. The current value allowed by the software is 2,500 (corresponding to 2,500 points per profile). Dependent on core storage for instructions and data, the maximum number of points per profile can be increased as needed.

M; (900) - The maximum number of profiles contained on the file of elevation data. If not accurately known, a number less than the actual value should be used, omitting some data. A larger value will result in a border of "0" elevation at the top. There is no limit on the size of this parameter at VWNG = 0. As VWNG increases, the only limit is the size of the plotter page. (Size of plot in inches is $M \cot(\text{PRJNG}) \sin(\text{VWNG}) \left(\frac{S}{N}\right) + s$ along the y-axis; along the x-axis it is $N \cot(\text{PRJNG}) \sin(\text{VWNG}) \left(\frac{S}{N}\right) + \frac{MS}{N}$).

DEM; (800) - The scaling factor applied to the input elevation data. The greater the value of DEM, the flatter the terrain will appear in the projection. For best results for most topography, DEM should be between 1/3 and 1/2 the difference between the maximum and minimum elevations to be plotted.

S; (15.0) - The desired length of the profiles of the output projection in inches on the plotter in the direction of the profiles (the y-axis). S should be chosen such that the entire plot will fit on the plotter (see equations in the Derivation of the Transformation Equations section). $\cot(\text{PRJNG}) \cot(\text{VWNG}) \frac{S}{N}$ should be between 0.0075 and 0.014 for best results with a Calcomp plotter.

CARD 2 - Input Parameters

ICODE; (0) - An integer, flag. Input 0 if program is to continue execution. Input -10 if program is to end. A DATA CARD WITH ICODE EQUAL TO -10 MUST FOLLOW THE FINAL SET OF DATA CARDS.

NSKIP; (0) - An integer parameter determining the number of points and profiles to be skipped. Thus, an NSKIP equal to 1 would skip every other profile and every other point within a profile. NSKIP should be used when it is desired to produce a coarse projection of major terrain features.

MSKIP; (0) - An integer parameter determining the number of profiles to be skipped in processing. MSKIP equal to 0 skips no profiles; MSKIP equal to 1 plots every other profile, etc. By deleting every other profile, the separation between profiles doubles, increasing the contrast between different types of terrain and decreasing the density of the projection.

CARD 3 - Parameters

PRJNG; (45.0) - The angle of projection of the data relative to the projection plane (see Oblique Projections section of this report for the density of the projection using PRJNG). PRJNG may assume any angle $0 < \text{PRJNG} \leq 90$. The scale of the receding axis relative to the horizontal (plotter y-) axis is $\cot(\text{PRJNG})$. Higher values of PRJNG give a shorter receding axis. Most frequently used values are 45.0 (scale equal to 1) and 67.0 (scale equal to 1/2).

VWNG: (45.0) - The angle of rotation of the projection about the plotter's x-axis. VWNG can assume any value between 0.0 and 90.0. Negative VWNG angles cannot be used with the current software. VWNG has the effect of off-setting successive profiles by $\cot(\text{PRJNG}) \cos(\text{VWNG}) \frac{S}{N}$. Low values of VWNG (30.0 to 45.0) are most comfortable perceptively. High values of VWNG are used to accommodate large quantities of data. A VWNG of 40.0 allows an infinite number of profiles.

CARD 4 - Input Parameters - Card 4 input parameters determine the minimum change in slope to be plotted, the interval over which the change in slope is evaluated, and the number of points around the critical point be plotted.

I1; (15) - An integer quantity defining the number of line segments on either side (along the plotter y-axis) of a relative maxima or minima over which the average slope in both directions is calculated. The slopes thus determined are averaged and used to determine the number of points to be plotted on either side of the maximum or minimum point. The slope determined is multiplied by C3, and the quantity I4 is added to yield the number of points on either side to be plotted. A value of approximately 15 for I1 seems to yield the best results. Smaller values pick up spurious features and the larger values are likely to extend beyond the desired feature.

I4; (6) - The integer parameter determining the number of points to be plotted on either side of a significant maximum or minimum point in addition to the number of points to be plotted on the basis of slope. Thus, I4 is a constant used to accentuate the visibility of the features detected by the Change-in-Sign-of-Slope logic and to enhance the plasticity of the projection. Empirical qualitative studies on this parameter suggest a value near 6.

C2; (0.25) - The minimum average slope around a relative maxima or minima necessary for the point to be plotted. If the average slope as determined over I1 points on either side is less than C2, the feature is considered insignificant and is not plotted. C2 may assume any position value, but qualitative analysis of plots by OBLQMP suggests that the optimum value for most terrain is approximately 0.25.

C3; (15.0) - The variable by which the average slope around a critical point is multiplied to determine the number of points to be plotted. The integer portion of the result of the multiplication yields the number of points on either side of the critical point, which are to be plotted in addition to the constant number of points to be plotted, I4. The value of C3 may be varied as varied emphasis of the feature depends on the slope. High values of C3 yield increased emphasis on those features with greater change in slope; low values decrease emphasis on the change in slope around the critical point. The optimum value of C3 for most types of terrain seems to be approximately 15.0, on the basis of plots produced by OBLQMP.

CARD 5 - Input Parameters - Card 5 input parameters determine the maximum separation of profiles plotted for closely spaced profiles to be considered significant and for the number of points to be plotted in such areas.

I5; (6) - The integer parameter determining the number of points on either side of the current point over which slope is determined. The slope determined is used to compute the number of points to be plotted around the critical point in addition to a constant number. Empirical studies of OBLQMP plots suggest that the slope should be computed over 6 points on either side of the current point for optimum points for most topography.

I6; (10) - The integer parameter determining the number of points to be plotted on either side of a point separated from a previous profile point by less than the parameter determining significance (CLOSER). These points plotted are in addition to those plotted on the basis of slope. As with the corresponding quantities of the other criteria, empirical study of plots by OBLQMP led to the conclusion that a value near 10 seemed optimal to clearly delineate the terrain associated with closely spaced profiles.

CLOSER (0.6) - The fraction of the nominal separation of successive profiles below which a feature is considered significant. This criteria takes MSKIP into account when some number of profiles is skipped, modifying the internal value. It does not take NSKIP into account. The nominal value of the separation of successive profiles is $\cot(\text{PRJNG}) \cos(\text{VWNG}) \left(\frac{S}{N}\right)$. This is the most difficult variable to optimize, particularly for flat topography. OBLQMP plots indicate that a value near 0.6 is optimum for relatively flat terrain with some detail.

NOTE: If CLOSER is greater than 2.0, the logic will be skipped, saving execution time. This recommended when the topography has little flat area.

C7; (15.0) - The value by which the slope in the region of a significant point (by this criteria) is multiplied. The result is integerized, yielding the number of points to be plotted on either side, in addition to I6. OBLQMP plots indicate that a relatively large value be used for gently sloping terrain; 15.0 seems adequate.

CARD 6 - Input Parameters - Card 6 input parameters are used to determine the length of the line to be drawn before a line disappears, or after it reappears. As with the other criteria, a constant number of points I9 are drawn, plus C10 times the slope points. Slope is computed over I8 points on either side, and averaged; C20 is a dummy parameter.

I8; (15) - The number of points on either side of a disappearing (or reappearing) point, over which slope is evaluated. The quantities are averaged and used to determine the number of points to be plotted. OBLQMP plots indicate that a value of 15 is optimum for the types of topography investigated.

I9; (10) - The number of points to be plotted after a line reappears (or before it disappears). These points are in addition to those determined by slope. OBLQMP plots suggest that a value of 10 is probably optimum for most types of terrain. Smaller values tend to make the object in the foreground appear indefinite; larger values cover too much area.

C10; (15.0) - The value by which the slope, calculated over I8 points on either side, is multiplied. The quantity is integerized to yield the points to be plotted in addition to I9.

C20; () - A dummy variable. No input value is necessary.

CARD 7 - Parameters-Change-in-Slope - Card 7 input parameters the minimum change in slope, over same number of points, which is necessary to plot a line of some length.

I11; (6) - The number of points on either side of the current point over which slope is to be evaluated. The two slopes are then used to determine the change in slope over the region. Since the terrain that this criterion is designed to consider significant is rapidly changing, a relatively new value for I22 is used (in comparison with corresponding values in slope criteria). A value of 6 seems to be optimum for this type of terrain, or the basis of OBLQMP plots.

I14; (6) - The minimum number of points to be plotted on either side of a point considered significant by this test. Since the change in slope will lead to a relatively larger number of points plotted on the basis of it, a relatively small number of points are always plotted. The optimum number is approximately 6. Larger values yield too many points, and smaller values do not adequately portray the feature.

C12; (0.18) - The minimum change in slope used to determine if the area is to be considered a significant topographic feature. Smaller values result in too much inconsequential detail for most terrain, larger values do not adequately delineate the features. A value near 0.18 seems optimum for the terrain projections produced thus far by OBLQMP.

NOTE: This is the only criteria determined solely on the basis of Change-in-Slope, and the only criteria to use this as a basis for determining the number of points to be plotted.

C13; (15.0) - The value by which the change in slope is multiplied to determine the number of points to be plotted around a significant feature. The resultant value is integerized, and many points are plotted around the feature, in addition to the minimum number, I14.

Input Elevation Data. The OBLQMP software was written to accept a grid of terrain elevation data that had equal spacing along both axes of the grid. The program accepts such data from a smoothed data file previously produced

by CONSACIIC software. The data is read in sequential profile format using unFORMATED FORTRAN READ statements, e.g.

```
READ (10) ID, JA, (D(J),T=1,9), (BLK), K=1,279), (E(L), L=1,12)
```

The B Array contains the pertinent elevation data. If data from a different source is to be plotted, the section of the program reading the data can be appropriately modified with ease.

Subsets of the input data can be plotted by utilizing NSKIP and MSKIP (see previous section). These transform only the subset of the data desired, retaining a uniform array. It should be noted that MSKIP increases the relative spacing between profiles in comparison with points along profiles.

Input/Output Unit Numbers. - The purpose of this section is to summarize, for easy reference, the various Input/Output unit restrictions and requirements.

<u>UNIT</u>	<u>ASSIGNED FOR</u>
(4) As Assigned	Smoothed Elevation Data Files
As Assigned	Calcomp Plot Tape
5	Input-Card Reader
6	Line Printer

Outputs.

Calcomp Plot Tape. When a plot of an oblique projection of the input elevation data is produced, the software produces a standard Calcomp Plot Tape on the unit assigned.

Line Printer Output. The normal line-printer output of the program includes all input parameters, some variables dependent on the input parameters (calculated internally), and processing results. A typical output follows:

NOTE: All items in parenthesis are additional comments added for this manual:


```

P= 1.V= 1. .5000 .5000 .8660SIVW= .8660
.7854 1.0472
I1= 15 I4= 6 C2= .175 C3= 15.000
I5= 15 I6= 10 CLOSER= 15.000 C7= 0.000
I8= 6I6= 12C10= .600
I11= 6I14= 6C12= .180C13= 15.000
ICODE= 1 NSKIP= 0 N=250 M=200
DY= .020000
IU= 1IST= 173IFN= 423
IU= 2IST= 173IFN= 423
IU= 3IST= 172IFN= 422
IU= 4IST= 171IFN= 421
IU= 5IST= 170IFN= 420
IU= 6IST= 169IFN= 419

```

Input Parameter Restrictions (Summary).

All Parameters Must be Positive.

<u>PARAMETER</u>	<u>MINIMUM</u>	<u>MAXIMUM</u>
N*	NONE	2500*
M*	NONE	$M \cot(\text{PRJNG}) \sin(\text{VWNG}) \left(\frac{S}{N}\right) + S$ must be less than plotter y-axis
S**	NONE	$M \cot(\text{PRJNG}) \cos(\text{VWNG}) \left(\frac{S}{N}\right) + \frac{MS}{N}$ must be less than plotter x axis
PRJNG	0	90
VWNG	0	90

*N and M are limited by array dimension, thus

$$M + (\cot(\text{PRJNG}) \sin(\text{VWNG}) (N)) \leq 2500$$

**S is limited by plotter dimensions

Program Physical Characteristics.

Physical length (approx.)	734
Storage requirements* (words)	9792
Data grid limitations	2500 X N*

*Data grid may contain an infinite number of profiles at PRJNG = 90, and up to 2,500 points per profile. At the penalty of increased core storage requirements, the points per profile can be further increased.